



New Developments in Magnet Insulation

VLHC Magnet Workshop

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New Insulation Developments

- CTD's experience with magnet insulation
- Goals for new magnet insulation
 - performance improvement
 - cost savings
- On-going development effort (SBIR's)
 - Wrappable inorganic insulation
 - Low viscosity, radiation resistant resins
- Future research concepts
 - Nb_3Tn and A15
 - HTS
 - NbTi



CTD's Insulation Experience

- Led US effort to develop and evaluate magnet insulation for ITER
 - ITER CS Model coil utilizes CTD insulation
 - NSTX coils
 - Repair of Alcator coils
- Participated in several accelerator magnet efforts
 - including: SSC, Fermilab VLHC, and LBNL high field coils
- Insulation materials used in research and commercial magnets in the US and around the world
 - Commercial MRI coils; mine sweepers; maglev; SC motors
 - NHMFL 45T superconducting coils



Current Insulation Products

- Vacuum-pressure impregnation systems: CTD-101
- One-part VPI systems: CTD-1PF/LV
- Glass pre-preg system with high radiation resistance: CTD-112P
- Glass pre-preg with 2 year RT out-life: CTD-1PFS
- Kapton® Adhesives:
 - CryoBond™ 105 (high radiation resistance)
 - CTD-1PFS/1Z (2 year RT out-life)
- RT Cure wet wind insulation (commercial MRI and Navy mine sweeper coils): CTD-521



Goals for New Insulation

Magnets

- Improve magnet performance
- Reduce magnet costs
- Different insulation for different conductors:
 - Nb_3Sn and A15
 - HTS
 - NbTi

CTD

- Be responsive to the needs of the community
- Develop technology which is reasonably attainable
- Pursue technology that makes sense in the market place



Enhanced Performance

- Mechanical Properties
 - Improve toughness
 - Increase modulus
 - Increase Strength
- Electrical Properties
 - Increase dielectric strengths
 - Enable close packing
- Thermal Properties
 - Match thermal contraction
 - Increase thermal conductivity
- Radiation
 - Reduce organic content
 - Reduce outgassing
- Chemical Compatibility
 - Address poisoning issues in A15 and HTS
- Reduce fabrication cost

Improved Processing

- Wind and react
 - co-react insulation with superconductor
 - reduce manufacturing time
 - reduce manufacturing cost
 - increased coil complexity
- Lower viscosity
- Longer pot life
- Lower processing temperatures
- Reduce health and environmental concerns
- Improve reliability
- Reduce risk
- Systematic optimizing of insulation system, processing and application procedures
- Develop insulation application processes that enable greater latitude for the coil designer



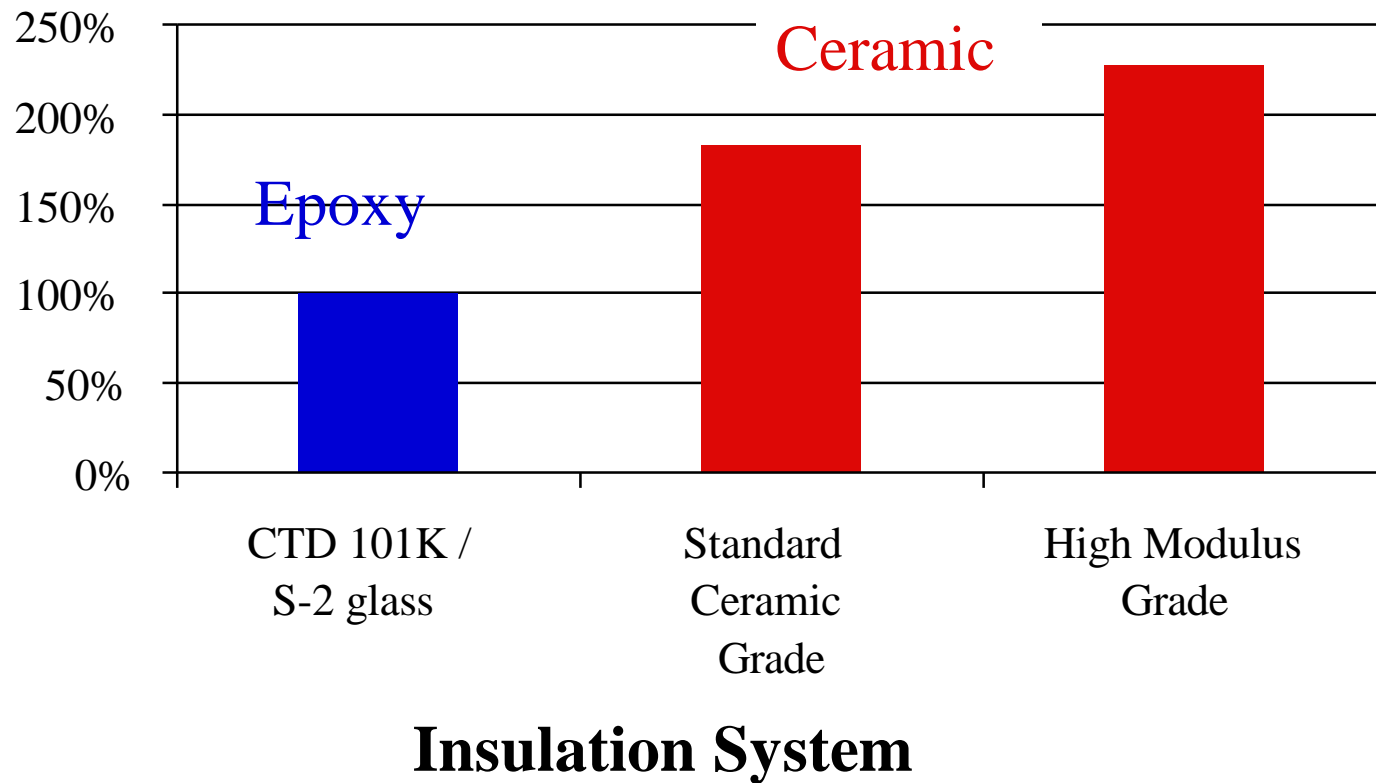
Wrappable Inorganic Insulation

On-going SBIR Phase II

- Description
 - High strength and modulus of a ceramic composite
 - Ease of processing of an organic insulation
 - Applied prior to heat treatment
 - Processed from 600°C to 900°C
 - Processing
 - apply ceramic insulation
 - cure and heat treat
 - impregnate with CTD-101K
- Benefits
 - Ideal for wind and react processing
 - Improved properties
 - doubled the modulus
- Accelerator coil evaluation
 - Fermilab & LBNL
 - Applying insulation directly to conductor cable
 - Pre-preg and VPI processing

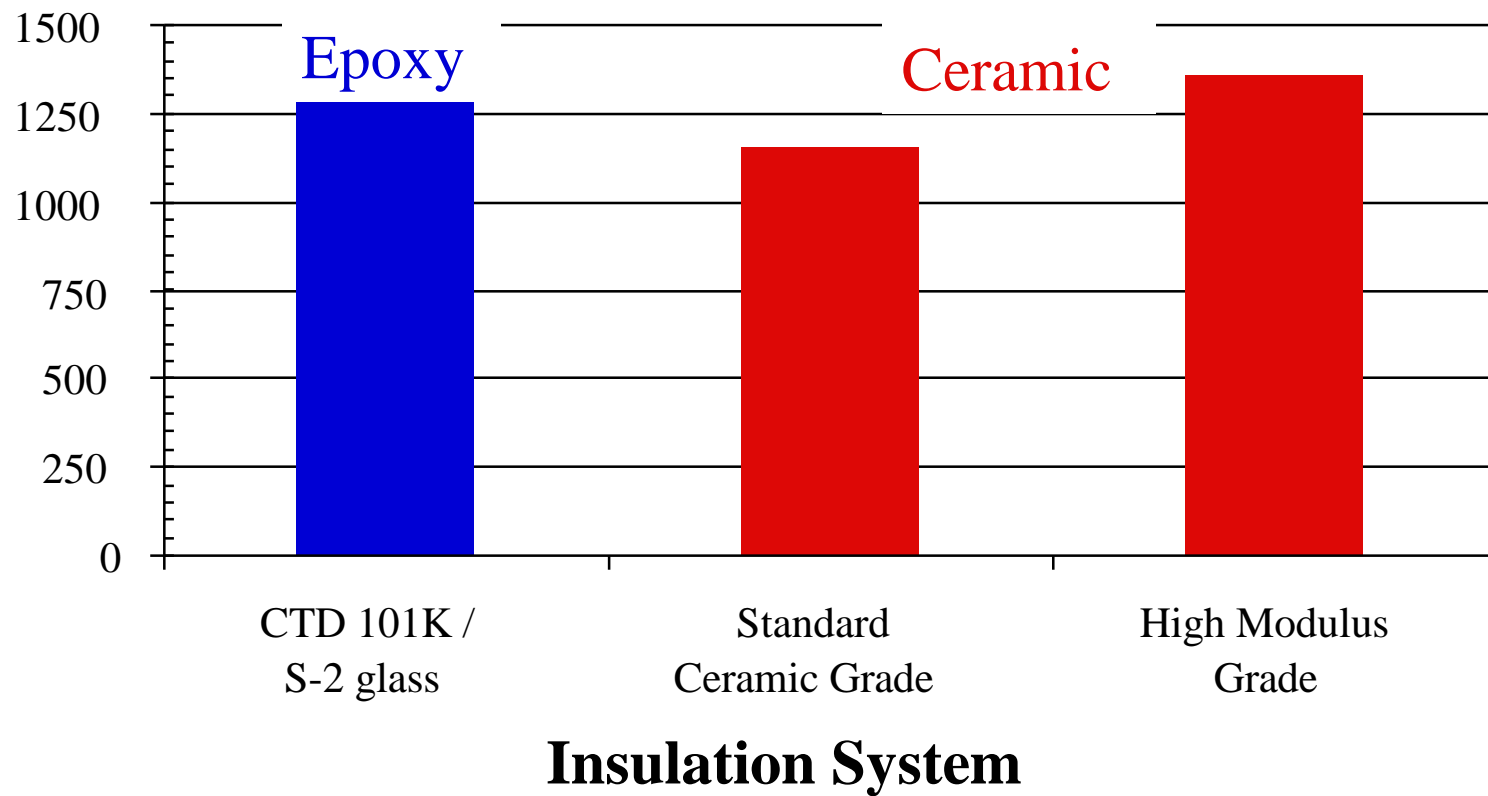


Compression Modulus

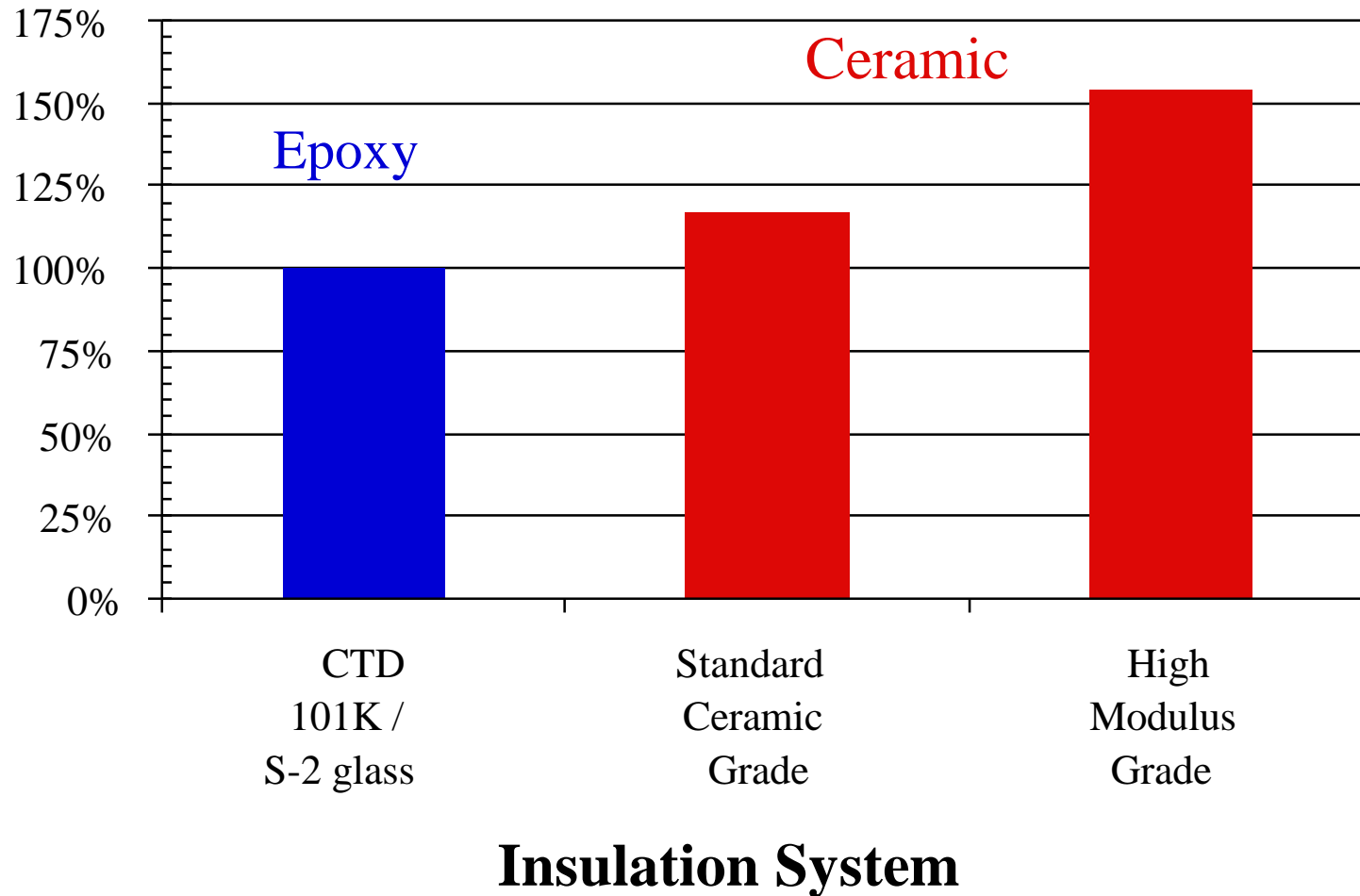




Compression Strength

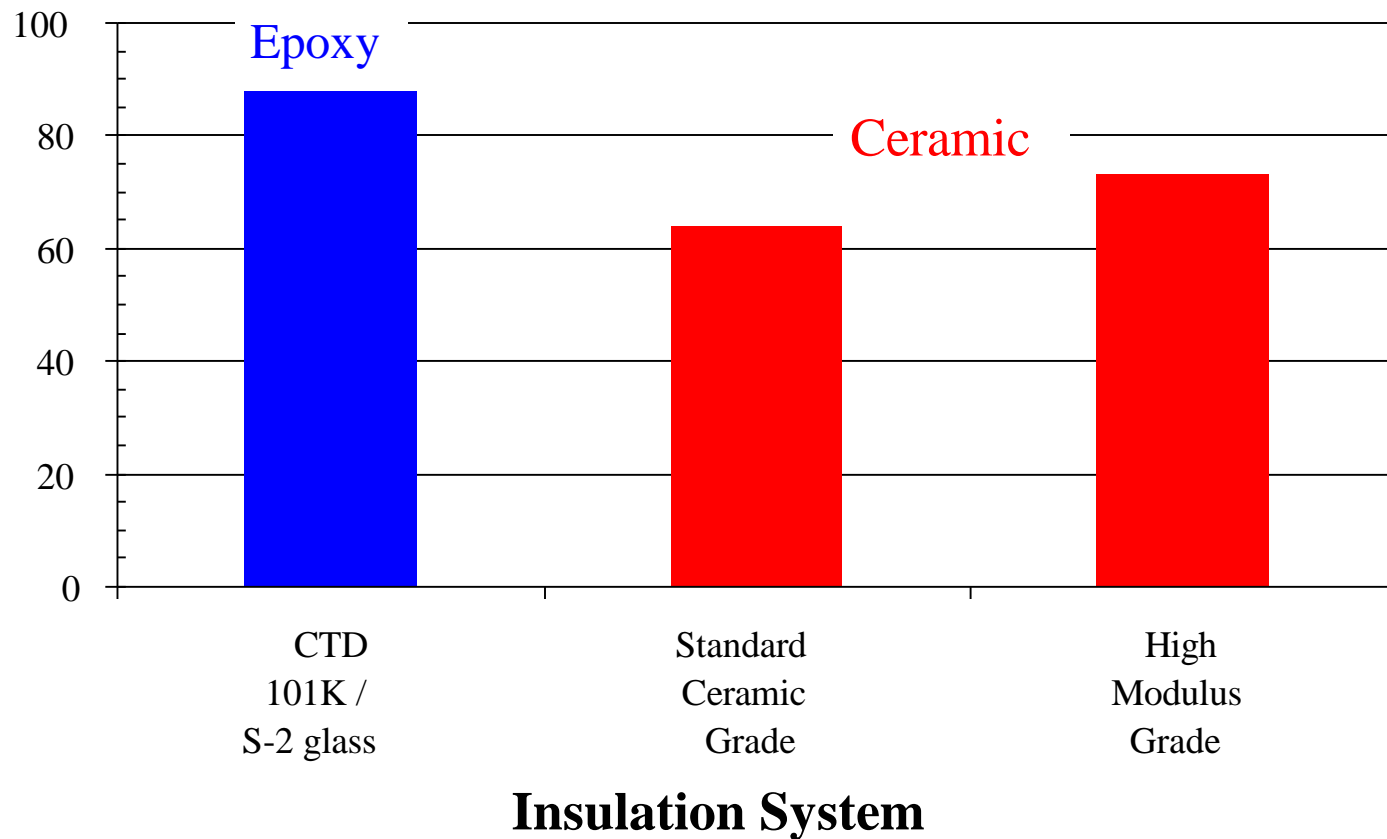


Flexural Modulus





Apparent Shear Strength





Low Viscosity, Radiation Resistant Insulation

On-going SBIR Phase I

- Goal
 - Develop stronger more radiation resistant resins
 - With low viscosity and long pot life at room temperature
- New Formulations
 - Based on aromatic chemical structure, similar to polyimides
 - Demonstrated greater radiation resistance than epoxies
 - Lower out gassing
 - Excellent mechanical properties
- Traditional aromatics
 - Normally solid at room temperature
 - Require high temperature and pressure cure
- Comparison to epoxies
 - Lower room temperature viscosity
 - Should enable lower temperature processing
 - Epoxies only ~50% aromatic

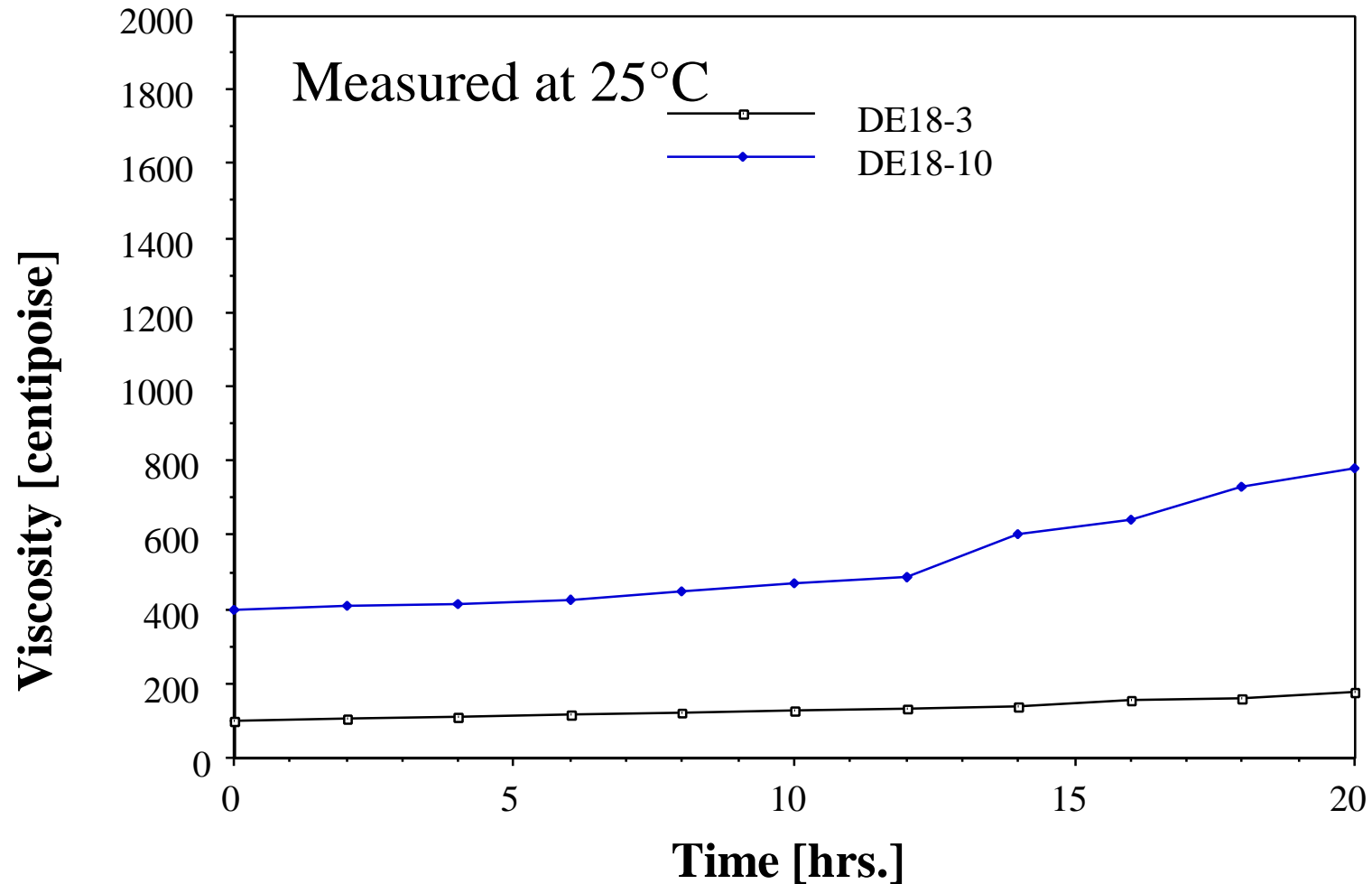


Phase I Accomplishments

- Successful hybridization of different chemistries
- Low initial viscosity at room temperature
 - As low as 100 centipoise at 25°C
- Long room temperature pot life
- Additional Phase I work planned
 - Differential Scanning Calorimetry (DSC)
 - Flow characterization
 - Coupon testing



Typical Viscosity Curves



Concepts for Nb_3Sn and A15 Coils

- All inorganic insulation
 - Increase mechanical properties
 - Reduce thermal shrinkage
 - Improve radiation resistance
- Benefits
 - Eliminate post heat treat epoxy impregnation
 - Obtain the highest/best combination
 - strength
 - modulus
 - Co-processed with superconductor
- Examine chemical compatibility

Concepts for HTS Coils

- Ceramic based co-processed insulation and barrier coatings
 - Chemical compatibility
 - Systems with and without barriers
 - especially looking zirconia based systems
 - Look at subtleties of different HTS conductors
 - Characterize Mechanical, electrical, and thermal properties
- Advanced Polymer based systems
 - enable close packing of conductor
 - ease of application onto brittle conductor



New Concepts for NbTi Coils

- Inorganic/Organic Hybrid Insulation
 - Low viscosity for ease of vacuum impregnation
 - cures similarly to an epoxy
 - High inorganic content
 - increased modulus
 - improved radiation resistance
 - lower thermal shrinkage
- Advanced B-stage adhesives and pre-preg resins for Kapton® and glass tape
- Combination Kapton®/Glass tape insulation
 - enabling close packing
 - Dielectric of Kapton®, Strength of glass



Want to Hear the Needs of the Community



Goals

Needs

Road Blocks

Cost Factors